Mechanistic understanding of mill operation

Arno Kwade, Institute for Particle Technology,
Braunschweig University of Technology

In several industries size reduction is an important process – either for breaking raw materials like minerals to fine particle sizes or for tailoring particles sizes of synthetic materials like active substances, pigments, cement or ceramics to achieve the demanded product properties. Due to the high variety in materials to be milled and the enormous particle size range from almost meter down to nanometer sizes, a large variety of mills working with different particle stressing principles exist. As particle breakage is an energy controlled micro process, the most important mill operation parameter is the specific energy input to achieve a certain material fineness, i.e. product quality. Therefore, signature plots (specific energy vs. product fineness) and size specific energies (specific energy consumed related to material mass finer than demanded size) are important characteristics.

After a basic classification of the various types and configurations of stressing, the energy flow from the mill motor to the stressed particles is discussed. As an important parameter, the energy transfer factor is introduced which describes the proportion of the energy transferred to the particles from the total energy introduced into the grinding chamber. In addition, the mechanistic approach to the mill function, i.e., the description of grinding processes, is presented in more detail: According to the so-called stress model, the comminution behavior of a mill is determined by three parameters: stress type, stress frequency, and stress energy distribution. To describe the result of a comminution process instead stress number and stress intensity should be applied in addition to the stress type. The stress intensity takes into account, in particular, which material mass is subjected to which stress energy. The effect of the mill types on the characteristic parameters is discussed in more detail.

In addition to the stress configuration, the transport of the material through the mill in continuous operation is decisive for the grinding result, but also for the specific energy requirement. On the one hand, transport dissipates a sometimes high proportion of the energy; on the other hand, it leads to a residence time distribution and different mill filling degrees, which significantly define the efficiency of the grinding process.

Based on this mechanistic background results of different mill operations from ball mills over impact mills to stirred media mills will be presented and evaluated. Beside size reduction efficiency also the impact of operation condition on machine wear will be tackled. Moreover, the potential to design, predict, control and optimize mill operations based on this knowledge will be discussed.